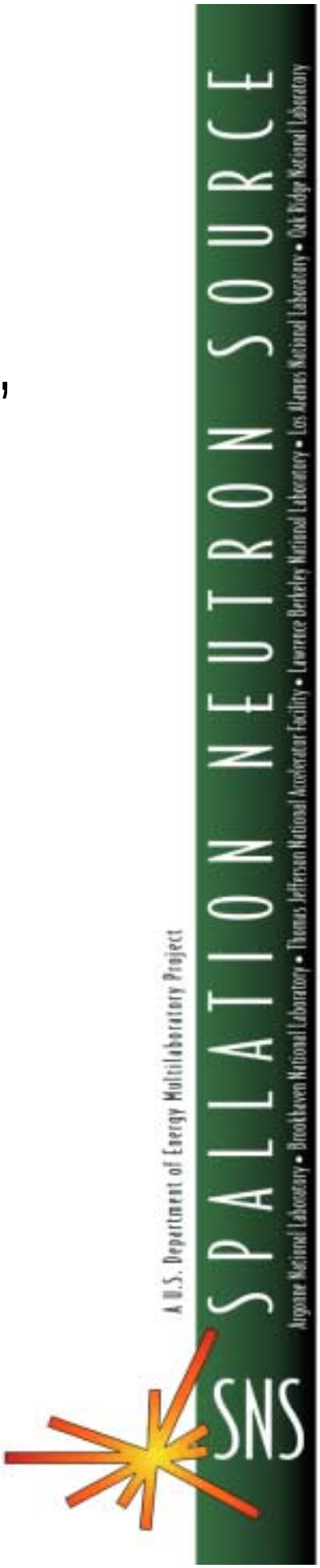
SNS 104010300-SR0002-R00

Low Level RF Control System Requirements for RFQ, Linac, and HEBT



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M.S. Champion

October 2002

Prepared for the
U.S. Department of Energy
Office of Science

UT-BATTELLE, LLC
managing
Spallation Neutron Source activities at
Argonne National Laboratory
Brookhaven National Laboratory
Thomas Jefferson National Accelerator Facility
Lawrence Berkeley National Laboratory
Los Alamos National Laboratory
Oak Ridge National Laboratory
under contract DE-AC05-00OR22725
for the
U.S. DEPARTMENT OF ENERGY

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October 2002

Mark Champion
SNS LLRF Team Leader
Date: 10/22/2002

George Dodson
SNS Accelerator Operations Head
Date: 22/Oct/02

Dave Gurd
SNS Accelerator Controls Head
Date: 22/Oct/02

Stuart Henderson
SNS Accelerator Physics Head
Date: October 22, 2002

Alex Ratti
LBNL LLRF Team Leader
Date: 10-26-2002

Tom Shea
SNS Accelerator Diagnostics Head
Date: 10-22-02

Hamid Shoaee
LANL LLRF Team Leader
Date: 10-26-02

Low Level RF Control System Requirements for RFQ, Linac and HEBT

This System Requirements Document for the SNS Low Level RF Control System was established as a result of the 26-27 September 2002 special review of the LLRF control systems. The System Requirements Document[1] and Design Criteria Document[2] for Linac Systems, along with documentation[3] specific to the existing LLRF control systems, were used for guidance in determining these requirements. Additional information was obtained in discussions between technical staff of LANL, LBNL, and ORNL.

The LLRF control system covered by this document will serve the following components of the SNS accelerator:

1. RFQ
2. Drift-Tube Linac
3. Coupled-Cavity Linac
4. Superconducting Linac
5. HEBT energy corrector cavities

Performance and Technical Requirements

1. Amplitude and Phase control to ±1% and ±1° during the beam-on time. These requirements shall tighten to ±0.5% and ±0.5° after CD-4 (30 Dec 2005). Adjustable trip points shall cause beam inhibit via the Machine Protection System in case of poor regulation. The RF drive and MPS shall be inhibited within 1μs of the detection and shall remain inhibited for the remainder of the pulse. They shall be re-enabled for the following pulse.

2. Setpoint curve capability. Provides for step, linear ramp and sine profiles during the cavity fill.

3. Scalar setpoints for amplitude and phase during the beam-on time.

4. Feed forward capability including adaptive feed forward. The implementation shall provide for operation with or without feed forward. When feed forward is enabled, the system shall provide for either static or adaptive operation. The feed forward implementation shall rely on tables that can be accessed via EPICS.

5. Filtering of the RF drive and/or cavity field probe signals to prevent excitation of nearby cavity modes and to reject nearby modes that are excited by the beam.

6. Adjustable (if applicable) PID parameters: K_P, K_I, K_D.

7. Variable frequency mode for:

    a. Resonance hunting
    b. Cavity warmup (normal conducting structures)

    This mode of operation shall be used whenever a cavity is brought into operation from an idle state. Resonance hunting provides for determining the cavity resonant frequency. For the superconducting linac the tuning error shall be reported as a process variable, and EPICS shall operate the stepper motor to tune the cavity frequency to 805 MHz. For the normal conducting

[1] System Requirements Document for WBS 1.4 Linac Systems (LANL), SNS104000000-SR0001-R00, June 2000.
[2] Design Criteria Document WBS1.4.1 Linac RF System, SNS104010000-DC0001-R00, Nov. 30, 2000.
[3] http://www.sns.gov/projectinfo/llrf

linac the tuning error shall be reported as a process variable, but instead of tuning the cavity, the system shall operate the cavity at high power and track the resonant frequency of the cavity as it warms up due to RF heating. In both cases, once the cavity is operating at the reference frequency, the system shall change to fixed frequency mode. The amplitude regulation requirement shall be relaxed to ±5% and there shall be no phase regulation requirement when in variable frequency mode.

8. Resonance control. The RF control system shall calculate the difference between the reference frequency (402.5 or 805 MHz) and the cavity resonant frequency during normal linac operation without impacting beam delivery. The frequency detuning (in Hz) shall be available as a process variable updated at a minimum rate of 0.2 Hz. The correction will be handled by EPICS, either via water temperature control for the normal conducting linac or by stepper motor control for the superconducting linac.

9. History buffers that provide for an EPICS display of the following waveforms:

    a. Incident (forward) RF Power
    b. Reflected RF Power
    c. Cavity Field
    d. I & Q Drive Signals
    e. Internal Diagnostic Signals, e.g., loop error, as necessary for system setup

    The waveforms shall be obtained at the machine repetition rate (typically 60 Hz). The EPICS display of these waveforms shall be updated on the occurrence of an event on the event link with a maximum update rate of 6 Hz. All signals shall be displayable in either amplitude/phase or real/imaginary format. At least 2 ms of waveform shall be displayed so that the cavity fill, beam-on, and cavity field decay can be observed. The display resolution shall be 4 μs or less. At least three of the five waveforms shall be displayable simultaneously.

10. High Power Protect input. The RF drive and MPS shall be inhibited within 1μs of the fault and shall remain inhibited for the remainder of the pulse. They shall be re-enabled for the following pulse if the fault has cleared.

11. Cavity arc and quench detection. The RF drive and MPS shall be inhibited within 1μs of the detection and shall remain inhibited for the remainder of the pulse. They shall be re-enabled for the following pulse if the fault has cleared.

12. Consecutive faults shall result in latching the RF drive and MPS inhibits to prevent automatic resumption of operation without operator intervention. The maximum number of permitted consecutive faults shall be settable by system experts.

13. Modes of operation. The LLRF control system must accommodate various modes of operation characterized mainly by the duration of beam-on time within the RF pulse, for example, 10, 50, 100, and 1000 μs beam macropulses. The RF pulse length shall not be changed to accommodate these modes.

Process Variables

A set of Common Process Variables shall be used by EPICS to control and monitor the LLRF control system. Operator screens shall use only these Common Process Variables and shall not distinguish between differences in the underlying hardware. A set of hardware-specific Special Process Variables shall be used for Expert screens.

Software / Firmware Requirements

Version Control

The Concurrent Versions System (CVS) shall be used for version control for all software, firmware, test benches and system models. The CVS Repository at ORNL can be accessed via http://ics-web1.sns.ornl.gov/. General information about CVS can be obtained at http://www.cvshome.org/.

FPGA Language

Verilog or VHDL shall be used.

Compatibility Requirements

The tools and methods used shall support portability and sharing of all codes between the partner labs.

Implementation Schedule

	FE / RFQ 21 Oct 2002	JLab Test Jan 2003	DTL1 22 Mar 2003	DTL1-6 01 Sep 2003	CCL 17 Feb 2004	SCL 15 Feb 2004	Linac Operations 30 Dec 2005
Feedback Control of Amplitude & Phase to ±1% and ±1°	X	X	X	X	X	X	X
Feedback Control of Amplitude & Phase to ±0.5% and ±0.5°	--	--	--	--	--	--	X
Setpoint Curve	--	--	X	X	X	X	X
Scalar Setpoints	X	X	X	X	X	X	X
Feed Forward	--	--	X	X	X	X	X
Adaptive Feed Forward	--	--	--	--	X	X	X
Adjustable PID Parameters	X	X	X	X	X	X	X
Resonance Hunting	X	--	X	X	X	X	X
Cavity Warmup	X	NA	X	X	X	NA	X
NC Resonance Control	X	NA	X	X	X	NA	X
SC Resonance Control	NA	--	NA	NA	NA	X	X
History Buffers	X	X	X	X	X	X	X
High Power Protect	X	--	X	X	X	X	X
Cavity Arc Detection	X	--	X	X	X	X	X
Cavity Quench Detection	NA	--	NA	NA	NA	X	X
Consecutive Fault Detection	X	--	X	X	X	X	X
Modes of Operation	X	X	X	X	X	X	X

Key: X required
-- not required
NA not applicable